CLAIMS

1. Apparatus for determining the position of an object within a body of a subject, comprising:

at least one acoustic wave generator, adapted to direct a first acoustic wave toward the body at a first frequency;

an acoustic tag adapted to be fixed to the object, the tag comprising a shell defining a cavity therein and a medium contained within the shell, such that responsive to incidence thereon of the first acoustic wave, the tag emits a second acoustic wave at a second frequency, different from the first frequency;

one or more detectors, adapted to detect the second acoustic wave and to generate signals responsive thereto; and

a signal processor, coupled to process the signals so as to determine coordinates of the object in the body.

2. Apparatus according to claim 1, wherein there is substantially no wired connection to the tag.

3. Apparatus according to claim 1, wherein the tag has an axis and is constructed so that responsive to incidence thereon of the first acoustic wave, the tag emits the second acoustic wave at the second frequency with a first pattern of intensity variation relative to the axis, and a third acoustic wave at a third frequency, different from the first and second frequencies, with a second pattern of intensity variation relative to the axis, and wherein responsive to detection of the second and third acoustic waves by the one or more detectors, the signal processor is adapted to determine an angular orientation of the object responsive to a difference between the first and second patterns.

4. Apparatus for determining the position of an object within a body of a subject, comprising:

at least one acoustic wave generator, adapted to direct acoustic waves toward the body over a range of frequencies, including at least first and second frequencies;

an acoustic tag adapted to be fixed to the object, the tag being constructed so as to reflect the acoustic waves at the first frequency with a first spatial pattern of intensity variation, and to reflect the acoustic waves at the second frequency with a second spatial pattern of intensity variation;

one or more detectors, adapted to detect the reflected acoustic waves and to generate signals responsive thereto; and

a signal processor, coupled to process the signals so as to determine an angular orientation coordinate of the object in the body responsive to a difference between the first and second spatial patterns.

5. Apparatus according to claim 4, wherein the signal processor is further adapted to determine position coordinates of the object responsive to the signals.

6. Apparatus according to claim 4, wherein the tag has an axis, and wherein the tag is constructed so that in the first spatial pattern, the acoustic waves are reflected predominantly in a first direction relative to the axis, while in the second spatial pattern, the acoustic waves are reflected predominantly in a second direction relative to the axis, different from the first direction.

7. Apparatus according to claim 4, wherein there is substantially no wired connection to the tag.

10012955.121001

8. Apparatus for determining the position of an object within a body of a subject, comprising:

at least one acoustic wave generator, adapted to direct acoustic waves toward the body;

a transducer adapted to be fixed to the object and constructed to emit electromagnetic radiation responsive to the acoustic waves with a response that varies depending on an orientation angle of the transducer relative to the at least one acoustic wave generator;

one or more detectors, adapted to detect the electromagnetic radiation emitted by the transducer and to generate signals responsive thereto; and

a signal processor, coupled to process the signals so as to determine an angular orientation coordinate of the object in the body.

9. Apparatus according to claim 8, wherein the transducer comprises a piezoelectric crystal, which is polarized so as to respond anisotropically to the acoustic waves.

10. Apparatus according to claim 9, wherein the piezoelectric crystal has multiple opposing faces, and wherein the transducer further comprises a plurality of resonant circuit elements having different, respective resonant frequencies, the circuit elements being coupled between respective pairs of the faces of the crystal so as to emit the electromagnetic radiation at the different resonant frequencies with respective amplitudes that vary responsive to the orientation angle of the transducer.

11. Apparatus according to claim 10, wherein the circuit elements comprise coils having different, respective values of inductance.

12. Apparatus according to claim 8, wherein the signal processor is further adapted to determine position coordinates of the object responsive to the signals.

13. Apparatus according to claim 8, wherein the transducer comprises a magnetostrictive element, which is shaped so as to respond anisotropically to the acoustic waves.

14. Apparatus according to claim 13, wherein the magnetostrictive element is shaped to as to focus the electromagnetic radiation that it emits.

15. Apparatus according to claim 8, wherein there is substantially no wired connection to the transducer.

16. Apparatus for determining the position of an object within a body of a subject, comprising:

at least one field generator, adapted to generate an electromagnetic field within the body;

a transducer adapted to be fixed to the object and constructed to emit acoustic waves responsive to the electromagnetic field;

one or more acoustic detectors, adapted to detect the acoustic waves emitted by the transducer and to generate signals responsive thereto; and

a signal processor, coupled to process the signals so as to determine coordinates of the object in the body.

17. Apparatus according to claim 16, wherein the transducer comprises a piezoelectric crystal, which is polarized so as to respond anisotropically to the electromagnetic field.

18. Apparatus according to claim 17, wherein the piezoelectric crystal has multiple opposing faces, and wherein the transducer further comprises a plurality of resonant circuit elements having different, respective resonant frequencies, the circuit elements being coupled between respective pairs of the faces of the crystal so as to cause the crystal to emit the acoustic waves at the different resonant frequencies with respective amplitudes that vary responsive to the orientation angle of the transducer.

19. Apparatus according to claim 18, wherein the circuit elements comprise coils having different, respective values of inductance.

20. Apparatus according to claim 16, wherein the transducer comprises a magnetoacoustic transducer.

21. Apparatus according to claim 20, wherein the transducer comprises a magnetostrictive material.

22. Apparatus according to claim 20, wherein the magnetoacoustic transducer is shaped so as to respond anisotropically to the electromagnetic field, so that the acoustic waves emitted thereby vary as a function of an orientation angle of the transducer relative to the at least one field generator, and wherein the signal processor is adapted to determine the orientation angle of the object responsive to the signals.

23. Apparatus according to claim 22, wherein the magnetoacoustic element is shaped to as to focus the electromagnetic radiation that it emits.

24. Apparatus according to claim 16, wherein there is substantially no wired connection to the transducer.

25. A method for determining the position of an object within a body of a subject, comprising:

fixing an acoustic tag to the object, the tag comprising a shell defining a cavity therein and a medium contained within the shell, such that responsive to incidence thereon of a first acoustic wave at a first frequency, the tag emits a second acoustic wave at a second frequency, different from the first frequency;

inserting the object into the body of the subject;

directing the first acoustic wave toward the body at the first frequency, causing the tag to emit the second acoustic wave at the second frequency;

detecting the second acoustic wave and generating signals responsive thereto; and

processing the signals so as to determine coordinates of the object in the body.

26. A method according to claim 25, wherein fixing the tag to the object comprises fixing the tag so that when the objected is inserted into the body, there is substantially no wired connection between the tag and circuitry outside the body.

27. A method according to claim 25, wherein the tag has an axis and is constructed so that responsive to incidence thereon of the first acoustic wave, the tag emits the second acoustic wave at the second frequency with a first pattern of

10595200 1021401

intensity variation relative to the axis, and a third acoustic wave at a third frequency, different from the first and second frequencies, with a second pattern of intensity variation relative to the axis, and comprising detecting the third acoustic wave and generating the signals responsive thereto, wherein processing the signals comprises determining an angular orientation of the object responsive to a difference between the first and second patterns.

28. A method for determining the position of an object within a body of a subject, comprising:

fixing an acoustic tag to the object, the tag being constructed so as to reflect acoustic waves at a first frequency with a first spatial pattern of intensity variation, and to reflect acoustic waves at a second frequency with a second spatial pattern of intensity variation;

inserting the object into the body of the subject;

directing the acoustic waves toward the body over a range of frequencies, including at least the first and second frequencies;

detecting the reflected acoustic waves and generating signals responsive thereto; and

processing the signals so as to determine an angular orientation coordinate of the object in the body responsive to a difference between the first and second spatial patterns.

29. A method according to claim 28, wherein processing the signals further comprises determining position coordinates of the object responsive to the signals.

30. A method according to claim 28, wherein the tag has an axis, and wherein the tag is constructed so that in the first

spatial pattern, the acoustic waves are reflected predominantly in a first direction relative to the axis, while in the second spatial pattern, the acoustic waves are reflected predominantly in a second direction relative to the axis, different from the first direction.

31. A method according to claim 28, wherein fixing the tag to the object comprises fixing the tag so that when the objected is inserted into the body, there is substantially no wired connection between the tag and circuitry outside the body.

32. A method for determining the position of an object within a body of a subject, comprising:

fixing a transducer to the object, the transducer being configured to emit electromagnetic radiation responsive to acoustic waves incident thereon with a response that varies depending on an orientation angle of the transducer relative to a source of the acoustic waves;

inserting the object into the body of the subject;

directing the acoustic waves toward the body;

detecting the electromagnetic radiation emitted by the transducer responsive to the acoustic waves, and generating signals responsive thereto; and

processing the signals so as to determine an angular orientation coordinate of the object in the body.

33. A method according to claim 32, wherein the transducer comprises a piezoelectric crystal, which is polarized so as to respond anisotropically to the acoustic waves.

34. A method according to claim 33, wherein the piezoelectric crystal has multiple opposing faces, and wherein the transducer further comprises a plurality of resonant circuit

elements having different, respective resonant frequencies, the circuit elements being coupled between respective pairs of the faces of the crystal so as to emit the electromagnetic radiation at the different resonant frequencies with respective amplitudes that vary responsive to the orientation angle of the transducer.

35. A method according to claim 34, wherein the circuit elements comprise coils having different, respective values of inductance.

36. A method according to claim 32, wherein processing the signals further comprises determining position coordinates of the object responsive to the signals.

37. A method according to claim 32, wherein the transducer comprises a magnetostrictive element, which is shaped so as to respond anisotropically to the acoustic waves.

38. A method according to claim 37, wherein the magnetostrictive element is shaped to as to focus the electromagnetic radiation that it emits.

39. A method according to claim 32, wherein fixing the transducer to the object comprises fixing the transducer so that when the objected is inserted into the body, there is substantially no wired connection between the transducer and circuitry outside the body.

40. A method for determining the position of an object within a body of a subject, comprising:

fixing a transducer to the object, the transducer being configured to emit acoustic waves responsive to an electromagnetic field that is incident thereon;

inserting the object into the body of the subject;

generating the electromagnetic field within the body;

detecting the acoustic waves emitted by the transducer and generating signals responsive thereto; and

processing the signals so as to determine coordinates of the object in the body.

41. A method according to claim 40, wherein the transducer comprises a piezoelectric crystal, which is polarized so as to respond anisotropically to the electromagnetic field.

42. A method according to claim 41, wherein the piezoelectric crystal has multiple opposing faces, and wherein the transducer further comprises a plurality of resonant circuit elements having different, respective resonant frequencies, the circuit elements being coupled between respective pairs of the faces of the crystal so as to cause the crystal to emit the acoustic waves at the different resonant frequencies with respective amplitudes that vary responsive to the orientation angle of the transducer.

43. A method according to claim 42, wherein the circuit elements comprise coils having different, respective values of inductance.

44. A method according to claim 40, wherein the transducer comprises a magnetoacoustic transducer.

45. A method according to claim 41, wherein the transducer comprises a magnetostrictive material.

46. A method according to claim 41, wherein the magnetoacoustic transducer is shaped so as to respond anisotropically to the electromagnetic field, so that the

acoustic waves emitted thereby vary as a function of an orientation angle of the transducer relative to the at least one field generator, and wherein processing the signals comprises determining the orientation angle of the object responsive to the signals.

47. A method according to claim 46, wherein the magnetoacoustic element is shaped to as to focus the electromagnetic radiation that it emits.

48. A method according to claim 40, wherein fixing the transducer to the object comprises fixing the transducer so that when the objected is inserted into the body, there is substantially no wired connection between the transducer and circuitry outside the body.